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NOTES ON THE PETROLOGY AND STRUCTURE OF THE PRECAMBRIAN METAMORPHIC ROCKS OF THE UPPER MERSEY-FORTH AREA

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ABSTRACT

Precambrian metamorphic rocks in the headwaters of the Mersey and Forth Rivers include the Howell Group (garnet- and mica-schists and quartzites), Fisher Group (quartzites and slates) and the Dove Schist (garnet- and mica-schist). The rocks were strongly deformed during two phases (F_1 and F_2) of the regional metamorphism of the Frenchman Orogeny; a third phase (F_3) may include both Precambrian and Palaeozoic movements. The rocks resemble those of Frenchman's Cap in their chronology of deformation and crystallization. It is postulated that the rocks were folded into the large recumbent Borradaile Fold during F_2 and then into a series of synforms and antiforms during the Devonian Tabberabberan Orogeny.

INTRODUCTION

The Precambrian rocks of the headwaters of the Mersey and Forth Rivers have been briefly described by Spry (1958) and are very similar to those at Frenchman's Cap (Spry, 1962b). The area (fig. 1) is covered by the Middlesex one-inch sheet of the Tasmanian Mines Department (Jennings, 1958).

The Precambrian rocks are overlain by Cambrian sediments just South of Lorinna, but like many other parts of the edge of the Tyennan Geanticline, the Cambrian Dundas Group is generally missing and Ordovician sediments rest directly on the metamorphic rocks. The unconformity between Ordovician and Precambrian rocks is not strongly angular and the dip and strike are similar even though garnet schist is overlain by unmetamorphosed sandstone. Devonian granite has intruded along the unconformity in several places.

South of the unconformity is a belt of garnet-schist (Dove Schist) followed to the south by a belt which is dominantly quartzitic (Fisher Group). Next in order going south along the Mersey River is the Arm Schist (garnet- and mica-schist) then the quartzite belt through Maggs Mountain (Maggs Quartzite or Fisher Group) and then the Howell Group of schists and quartzites which extend further south for many miles (fig. 1).

It will be shown that two periods of deformation (F_1 and F_2) occurred during the regional metamorphism which is considered to be the Frenchman Orogeny (Spry, 1962a). Structures related to a third tectonic event (F_3) are not subdivided here and probably range in age from Precambrian to Devonian.

PETROLOGY

The lithology of the various rock groups will be first described and then the possible structural, stratigraphic and petrological relations discussed. Study of similar rocks at Frenchman's Cap (Spry, in press) has shown that the history of the metamorphic rocks can be best determined by analysing the chronology of crystallization and deformation. Bedding is referred to as S_0, the foliation produced during F_1 is S_1, S_2 was formed during F_2 and S_3 during F_3.

DOVE SCHIST

Dark coloured, rather fine-grained mica schists are well exposed along the Mersey Forestry Road for several miles north of the junction of the Mersey and Fisher Rivers. Similar schists outcrop further west along the Forth River and the type locality is at the quarry just west of the Forth River on the road from Lorinna to the Dove Mill (Spry, 1958).

The schists are strongly foliated with a colour banding parallel to the foliation. The lithology is uniform and interbedded quartzites are rare. Lineation is uncommon.

The schists contain quartz, muscovite, chlorite and albite with garnet in many specimens but biotite in only a few. Accessories are graphite, iron ore, zircon and tourmaline.

The main difference between the varieties of Dove Schist lies in their fabric and five specimens (7372*, 7382, 7370, 7383 and 7392) from the Mersey Forestry Road, 3 miles north of the Fisher - Mersey junction illustrate this. No. 7372 is simplest and is fine-grained and composed mainly of sub-parallel flakes of muscovite with small lenticular grains or aggregates of quartz and small porphyroblasts of garnet. The foliation is made up of interweaving layers of mica dividing the rock into lenses. Chlorite forms small discontinuous layers. Albite occurs as small lenticular porphyroblasts with various *Si* (S-internal, the S-surface within a crystal) structures. In some grains the *Si* are sigmoidal and trail off into *Se* (S-external, the S-surface outside of the crystal) and are thus syntectonic, others contain straight *Si* which pass out into *Se* and are posttectonic, some contain *Si* which are discordant with *Se* and thus are pretectonic to the foliation.

Muscovite and chlorite generally occur as well-oriented parallel flakes (syntectonic) but randomly oriented posttectonic flakes are also present. Other muscovite crystals occur in thin quartzose lenses which are parallel to the foliation but which contain mica flakes oblique to the foliation. It will be shown that these flakes represent an old foliation S_1 and that the major foliation is S_2. The latter is slightly crumpled and a foliation S_3 has developed along the appressed limbs of the folds; some growth of muscovite and chlorite has occurred along S_3. No mineral growth was associated with S_3 at Frenchman's Cap.

No. 7382 is similar in outward appearance to the previous specimen and outcrops close to it but is considerably more complex. It contains three distinct foliations. The major schistosity S_2 is formed by thin, closely spaced parallel layers alternatively richer in muscovite or in quartz. An older foliation S_1 occurs as tightly folded remnants between the layers of S_2. A third folation S_3 runs obliquely across the rock as widely spaced, straight fractures with a little randomly oriented posttectonic biotite (fig. 2g).

Muscovite occurs as small flakes along both S_1 and S_2 and is probably syntectonic to F_1 and F_2. Garnet forms small structureless porphyroblasts which do not disturb the surrounding micas; some have 'pressure tails' of quartz in S_2 and thus are pretectonic to F_2 and probably posttectonic to F_1. Albite forms small ragged crystals with dusty trails (fig. 2b) concordant with S_2 and are possibly posttectonic to F_2.

Biotite occurs in a number of forms. Greenish flakes along S_3 are posttectonic to F_3 and appear to be the last mineral to crystallise. Large ragged and bent flakes of rusty brown colour appear to pre-date S_2 and to be posttectonic to S_1. Green biotite occurs in lenses along S_2 but the cleavage is perpendicular to the lens (fig. 2c); trails of tiny dusty inclusions pass unbroken from S_2 through the micas which consequently are posttectonic to S_2 (fig. 2d).

No. 7370 is a fine grained, irregularly schistose rock with porphyroblasts of albite set in a matrix of muscovite, quartz, garnet and chlorite. The dominant schistosity is S_2 and barely-discernible remnants of S_1 remain. The correlation of foliations e.g., S_2, from specimen to specimen is made from continuity in the field and is independent of petrographic criteria as seen under the microscope.

The albite forms spongy porphyroblasts which are either untwinned or have simple twins on the Albite Law. The outer parts of the crystals have trails of inclusions continuous with lines of grains in S_2 and are clearly posttectonic to S_2. The cores of the albites extinguish differently from the rims and thus have a slightly different composition; central inclusions are either randomly arranged or absent. The cores might be pretectonic to S_2.

Garnet forms small crystals in the core of the albites and in the schistose matrix; both types are of similar size and it seems probable that all the garnet crystallized at an early stage.

No. 7383 contains a foliation which may be S_1 or S_2. Garnet is absent. Albite, tourmaline, chlorite, biotite and muscovite are postectonic to the folded foliation (fig. 2e).

No. 7392 is mineralogically simple in that it consists of quartz, biotite and muscovite with a little albite. but its structure is complex. S_1 is recognizable as a very tightly folded surface cut by S_2 which is itself folded. The rock consists of alternate lenses of quartz and mica with the orientation of the mica depending on its position within the folded S-surfaces. Muscovite has crystallized syntectonically along S_1 and S_2 and posttectonically in the cores of some folds in S_2. Albite is posttectonic to S_2 and biotite appears to be largely posttectonic to S_2 as it forms unbent flakes obliquely across some folds of S_2.

Specimens of schist from the Forth River are essentially similar. Specimen No. 7371 from the quarry at the type-locality is a lustrous greenish rock. It is composed chiefly of quartz, muscovite, and chlorite with accessory garnet, tourmaline, zircon and rutile and the fabric in thin section is very irregular (fig. 2f). The rock consists of alternate layers of muscovite plus quartz and of fine-grained chlorite; the layers have been tightly folded then disrupted so that isolated fold-hinges and twisted limbs remain. The flakes within the layers are discordant with the boundaries of the layers. The tiny chlorites form a matted aggregate in which the flakes are diversely oriented with only a slight tendency for alignment in zones, particularly along the margins of the layers.

* Numbers refer to specimens in the collection of the Department of Geology, University of Tasmania.

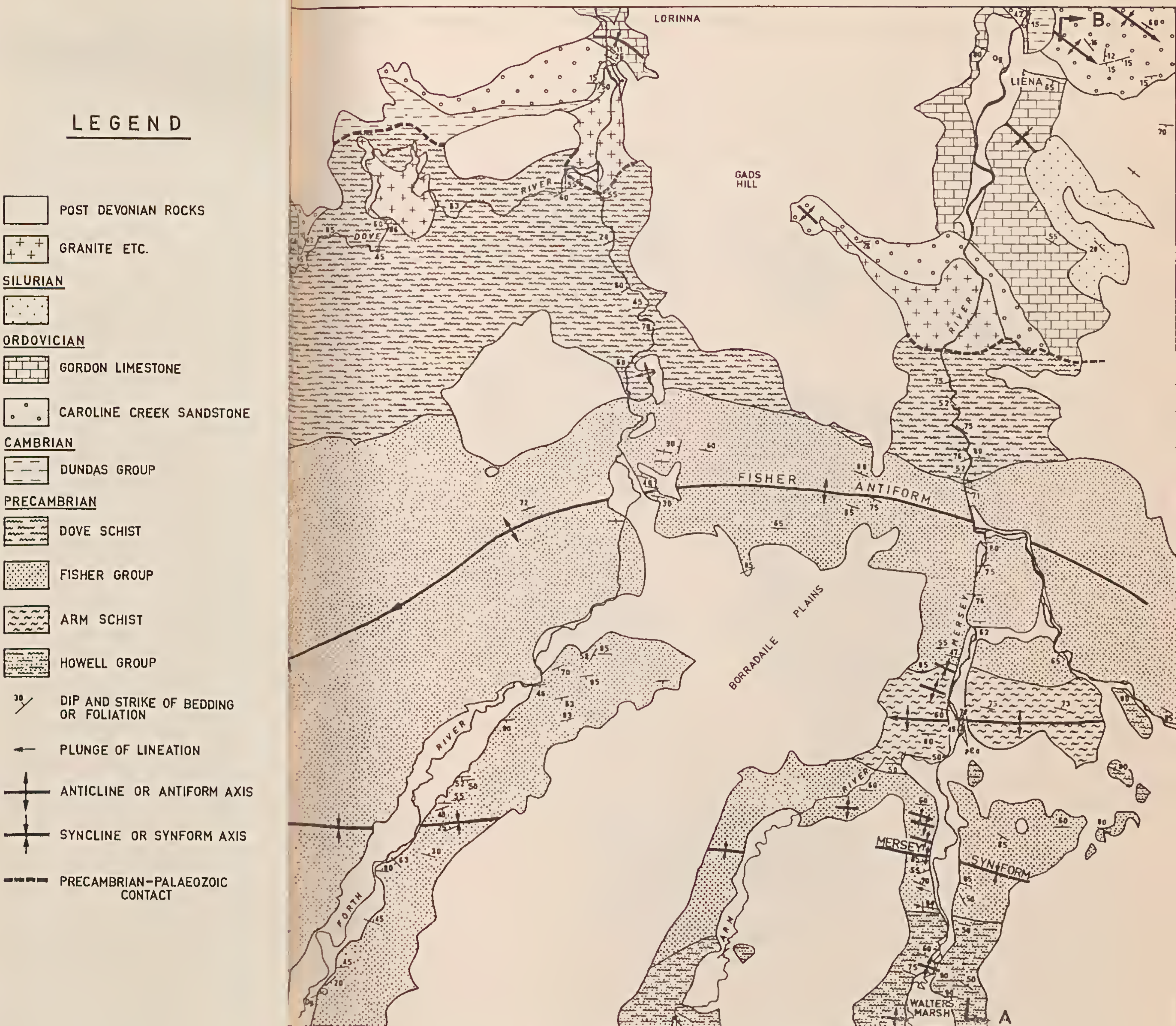

Fig. 1.—Geology of the Mersey-Forth Area. Based on Spry (1958) and Jennings (1958).

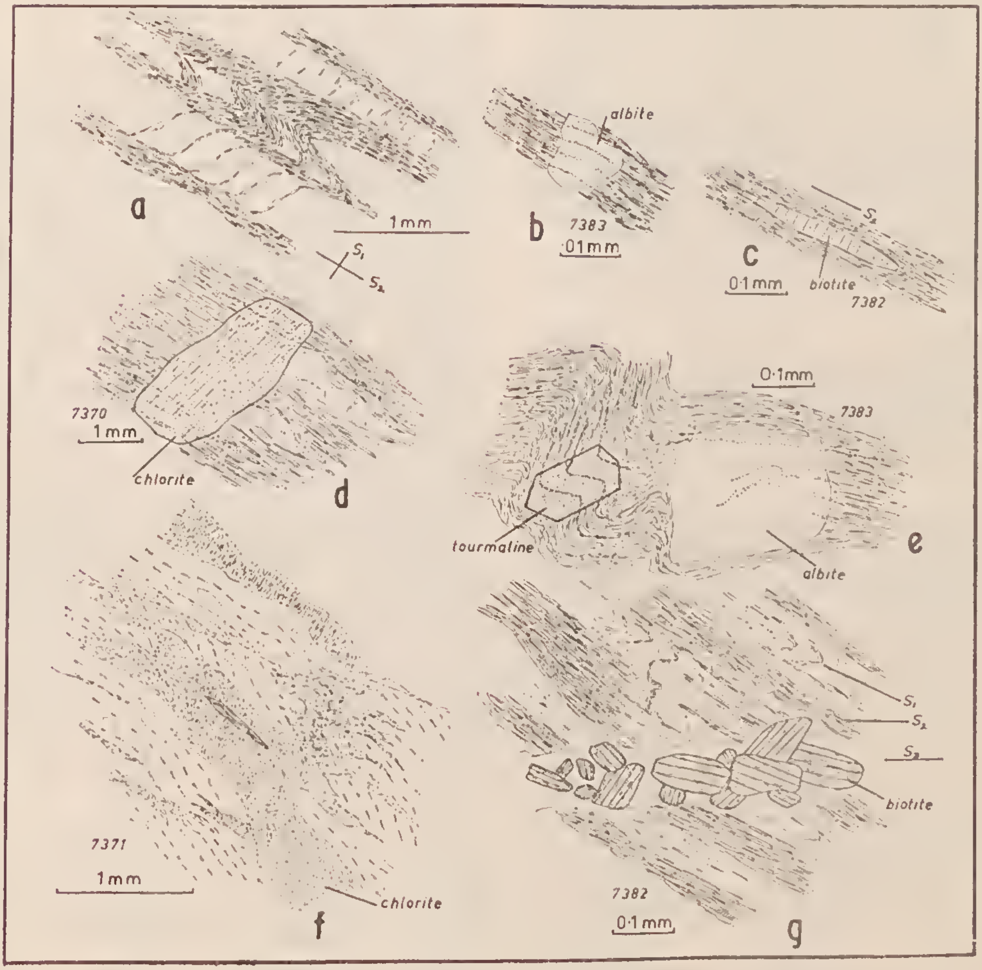

Fig. 2.—Textures of some schists :

(a) Folded S_1 remnants within planar S_2.
(b) Helicitic structure in posttectonic albite.
(c) Lenticular flakes of biotite elongate along S_2 but with cleavage perpendicular to S_2.
(d) Helicitic structure in chlorite, posttectonic to S_2.
(c) Helicitic structure in tourmaline and albite, posttectonic to S_2.
(f) Complex structure of Dove Schist.
(g) Posttectonic biotite along S_3.

The development of the fabric is difficult to interpret but by comparison with the structure in adjacent rocks it is likely that the parallel chlorite flakes and lines of muscovite flakes mark S_1 and that the banding, S_2, has been tightly folded.

An analysis (Table 1) shows high alumina and silica ; the low lime is typical of Tasmanian Precambrian schists. The analysis suggests that the chlorite is an iron-alumina variety.

No. 7368 which is a greenish schist, 3 miles west of the Dove Mill, shows the major foliation at about 20° to a compositional banding which might be bedding. Under the microscope, the texture is irregular and the foliations not well developed. Muscovite, quartz, chlorite, albite and a little biotite are present. Irregular layers of mica trend in one direction to give a foliation, but many micas are oriented at various angles to the foliation. Two generations of biotite include large, bent, partially chloritized flakes which are pretectonic to the foliation.

Fabric evolution

It is difficult to determine exactly what happened in the early stages. Bedding (S_0) is not preserved although dusty *Si* in chlorite and albite of no. 7366 (discordant to both S_1 and S_2) may represent bedding.

The fabric of the Dove Schist has evolved in the following way :

F_1 { Bedding (S_0) was folded and an early foliation S_1 produced by syntectonic growth of quartz and muscovite. Brown biotite and garnet were probably formed. Some biotite was chloritized posttectonically.

F_2 { The major foliation S_2 was formed during folding and transposition of S_1. Syntectonic growth of quartz and muscovite; posttectonic growth of albite, chlorite, biotite and tourmaline. Chloritization of garnet and biotite.

F_3 { S_2 was folded with the production of a sporadic fracture cleavage S_3. Some posttectonic growth of chlorite, green biotite and quartz.

HOWELL GROUP

Spry (1958) named the group of schists and quartzites along the western side of the Mersey valley, south of Walter's Marsh, the Howell Group. A narrow belt of schist and minor quartzite near the Arm-Mersey junction was named the Arm Schist and was regarded as possibly a distinct formation although the lithological similarity with the Howell Group was recognized. Jennings (1958) grouped the Arm Schist in the Howell Group. Stratigraphic equivalence cannot be either proved or disproved but the structural interpretation advanced later regards the Arm Schist as a formation in the Howell Group. In any petrological discussion there is no reason to separate them as the lithologies appear identical.

The schists as a whole are composed of muscovite, quartz, garnet, albite, chlorite and biotite with accessory tourmaline and rutile. The two main varieties are quartz - muscovite - albite - garnet schist, and quartz-muscovite-biotite schist.

Examples of the first group (7388, 7401 and 7374 are coarse-grained, knotted and strongly foliated rocks. Under the microscope they consist of about 45% quartz, 25% muscovite, 20% albite, 5% garnet and 4% chlorite; rutile, apatite and tourmaline are accessories. The analysis (Table 1) shows the moderate silica, low lime

TABLE I

	1	2	3	4	5	6
SiO_2	62.50	93.52	72.56	70.82	76.92	64.76
Al_2O_3	19.70	3.63	15.03	16.72	12.08	19.00
Fe_2O_3	0.75	0.28	1.85	0.53	0.68	1.07
FeO	5.59	0.38	1.02	1.28	1.89	3.20
MgO	1.72	0.14	1.07	1.22	1.61	1.16
CaO	0.48	0.04	0.04	0.39	Tr	0.08
Na_2O	0.11	0.10	1.11	1.02	1.47	1.72
K_2O	4.34	2.15	3.91	4.24	2.59	4.35
H_2O+	3.94	0.20	2.34	2.80	1.86	2.98
H_2O-	0.11	nil	0.20	0.20	0.03	0.12
MnO	0.05	0.01	0.01	0.03	0.01	0.04
TiO_2	0.62	0.05	0.62	0.77	0.42	0.88
P_2O_5	0.07	nil	0.03	0.07	0.04	0.08
	99.98	100.50	99.29	99.41	99.60	99.44

1. Schist, 7371, Dove Schist, Dove Mill.
2. Quartzite, Fisher Group, Mersey River.
3. Banded slate, 7390, Fisher Group, Mersey River.
4. Banded slate, 7390, Fisher Group, Mersey River. (anal. Avery and Anderson).
5. Mica schist, 7387, Howell Group, Walter's Marsh.
6. Mica schist, 7388, Howell Group, Mersey River.

and high potash typical of Tasmanian Precambrian mica schists.

Large (2mm.) prismatic porphyroblasts of albite are set in an irregularly schistose matrix of quartz and muscovite. One foliation (S_2) is dominant and is formed by subparallel mica flakes and by alternating lenticular layers rich in quartz or in muscovite. A younger foliation (S_3) occurs as sporadic shear planes at about 15° to S_2; growth of a little quartz and chlorite has taken place along these surfaces. The remains of an older S-surface occurs as contorted *Si* within albite.

The strongly contorted *Si* in the albite are not found elsewhere in the rock and consist of trails of tiny opaque grains, apparently graphite. The first stage appears to have been the folding of a surface which may have been S_0 or S_1 with little evidence of syntectonic growth. The albite encloses a little quartz, idoblastic tourmaline and garnet so that these three minerals predated its formation, but the main growth of a foliation formed by muscovite postdated the albite. The feldspar is posttectonic to S_1. A few scattered, bent flakes of partially or wholly chloritized biotite which contain *Si* somewhat similar to those in the albite, are regarded as of similar age. The major part of the muscovite and quartz outline S_2 and are syntectonic. The garnet contains a few vague *Si* and has the same relationship to muscovite as the albite (the mica wraps around it) so that it also predates S_2. Within the layers of S_2 some muscovite flakes outline fragmentary folds and this is probably folded S_1. Some muscovite flakes grow randomly across the major foliation and thus are posttectonic to S_2. Some quartz and chlorite crystallized along S_3; chlorite has replaced garnet as a late, nonoriented aggregate.

No. 7401 shows some slight differences. The albite porphyroblasts contain *Si* which are traced out, not only by tightly contorted dusty inclusions (S_0), but also by gently curved lines of elongate quartz crystals (S_1). This indicates some growth of quartz prior to the albite formation. Traces of a folded S-surface (S_1) older than the major foliation (S_2) are present as fold cores and lenses containing parallel muscovites oblique to S_2.

Brown biotite is abundant. Some large flakes enclose dusty *Si* trails and also muscovite flakes and are posttectonic to S_1. A few small biotite flakes are enclosed in albite and could be early posttectonic to S_2. A large proportion of the smaller biotites are parallel to the muscovite in S_2 and are probably syntectonic to this stage.

A little chlorite is present, most of it clearly derived from garnet. It commonly forms an envelope to the garnet crystals and forms part of S_2. It would appear that chlorite is syntectonic to S_2 but garnet is older and probably associated with S_1.

No. 7374 lacks chlorite; in this specimen biotite forms an envelope to the garnet and appears to form by reaction between muscovite and garnet. Many garnets show snowball structure and are syntectonic to S_1; they are partly replaced by randomly oriented biotite which is posttectonic.

Quartz-muscovite-biotite schists (such as 7399 and 7408) are richer in quartz than the schists in the previous group, contain much larger muscovite flakes, are not so strongly banded, have only rare garnet, and contain albite but not as porphyroblasts.

The foliation produced by parallel muscovite flakes, thin layers of muscovite and the elongation of some quartz, has been contorted. This foliation is probably equivalent to the major foliation S_2 of the other schists but clearly recognizable relicts of S_1 are uncommon (e.g. No. 7386). Albite encloses round quartz crystals and rare garnets but no *Si* are clearly recognizable.

Muscovite flakes are bent around the small folds but the biotite which averages about 1/20th of the size of the muscovite is fresh and unbent. It is intergrown with the muscovite and appears to replace it.

The order of crystallization was probably as in Table II.

Quartzites

Beds of quartzite up to a hundred or so feet in thickness and varying from vitreous to saccharoidal, and massive to foliated, occur within the Howell Group (e.g. 7397, 7400, 7402 and 7404). The quartzite core of an overturned anticline is exposed under the bridge across the Mersey River at Walter's Marsh. A thin-section cut normal to the lineation of specimen 7397 from the Walter's Marsh bridge is medium grained and granular. Quartz is not noticeably elongate but a weak foliation is produced by tiny, sparse, sub-parallel muscovite and biotite flakes. The quartz grains are slightly undulose and contain many cracks.

No. 7404 from the same locality is finer grained but is more strongly foliated; the parallelism of micas is more pronounced and the quartz grains are slightly elongate.

FISHER GROUP

The Fisher Group consists of the quartzites and slates along the Mersey River between a point about ½ a mile north of the Arm River junction and a point about ½ a mile north of the Fisher River junction.

The group is dominantly composed of white quartzite. Some is very thickly bedded and massive with ripple marks and cross bedding. Bedding is clearly visible and many of the rocks are only poorly foliated and lineated; folds are rarely visible. The pelitic members are black, laminated siliceous slates which are strongly cleaved and possess small tight folds.

The quartzite at Maggs Mountain was regarded as possibly a separate formation Spry (1958) and named the Maggs Quartzite. The mapping of Jennings (1958) further west indicated that the Fisher Group and Maggs Quartzite are continuous. Petrographic examination shows that the two are lithologically indistinguishable and so the term "Maggs Quartzite" is not used further.

Quartzite

The rocks are dominantly composed of quartz with albite and microcline and minor amounts of rutile and tourmaline as accessories. The analysis in Table 1 is that of a feldspathic sandstone with about 6% of feldspar, mostly microcline.

The main variation is in the texture. *No. 7375* from the Forth River, ½ a mile north of Gisborne's Hut, is a coarse white massive quartzite with traces of small isoclinal folds visible on a polished surface. A weak foliation is parallel to the axial surface of the folds.

Under the microscope the rock has a pronounced mortar texture; large parallel lenticular quartz grains with strong undulose extinction are set in a fine-grained matrix containing parallel muscovite flakes and equigranular quartz grains. A little fresh pretectonic microcline is present.

The mortar texture is present in 7405 but is less clear in 7389 and 7394 and barely recognizable in 7398.

In these specimens the proportion of large relict grains is very much smaller and the matrix is coarser in grain with undulose, elongate and lenticular crystals with blurred margins. The feldspars occur as well-rounded crystals commonly surrounded by a layer of tiny muscovite flakes. A feldspathic quartzite (No. 7385) from Maggs Mountain is more strongly recrystallized and foliated with no signs of mortar texture.

No. 7373 from the track along the Forth River, 1 mile north of Gisborne's Hut, has a weak cleavage close to the bedding and a strong lineation due to irregular fine ribbing. In a section cut normal to the lineation the texture is most unusual and quite unlike any of the other quartzites. The quartz grains are lenticular and feathery with sutured margins; they are strongly undulose and have a preferred orientation.

Petrofabric analyses (Spry, in press) show that some ripplemarked quartzites are virtually undeformed and have no preferred orientation of quartz whereas others are more deformed with a weak fabric.

Slates

Black slaty rocks occur among the quartzites of the Fisher Group but lack of outcrop has prevented mapping of their distribution. The rocks are thinly bedded, siliceous, dark in colour, somewhat glossy and might be called either slates or low grade phyllites. Very tight shear folds from a few millimetres to a few centimetres across are prominent (examples include 7406 and 7390).

The slate is composed of quartz, fine-grained muscovite and a little chlorite with accessory zircon, tourmaline and iron ore. Two chemical analyses of a specimen from the western side of the Mersey River, midway between the Arm and the Fisher Rivers, are given in Table 1. The rock was originally a siliceous siltstone and is rich in silica, alumina and potash, but poor in lime and iron. It is similar mineralogically and chemically to a phyllite from the Mary Group (Spry, 1962b) but is quite different in fabric. It is not chemically dissimilar from the schist (7387) from the Howell Group but has less silica (5%), more alumina (4%) and more potash (2%).

Under the micriscope, bedding (S_0) is visible as layers differing in grainsize (particularly quartz) and in the relative proportions of quartz and muscovite; chlorite occurs as tiny dark green aggregates and zircon (some quite angular) is abundant in some layers. A single strong foliation (S_1 ?) produced by parallelism of micas and by elongation of quartz grains has been folded with extreme thickening in the crests and troughs and thinning on the limbs; the folds are asymmetric and almost isoclinal. In some parts the bedding has been completely sheared out but in others can be seen to have been displaced in segments by the foliation. The bedding has a frayed appearance where it is cut by the foliation.

STRUCTURE

PRECAMBRIAN STRUCTURES

Bedding (S_0) is only recognizable with certainty in some of the more massive Fisher Group quartzites where it shows ripple marks and cross bedding. Compositional banding in Fisher Group slates is not much disturbed tectonically and is almost certainly bedding also. The contacts between major quartzites and schists in the Howell Group are bedding planes along which considerable tectonic movement has taken place.

Compositional banding on a small scale in Dove and Howell schists is due to alternations of quartz and musiovite-rich layers and is a foliation (S_2) much later than bedding. If the oldest S-surface is taken to be bedding (and this is by no means certain) it has been isoclinally folded, sheared through by later foliations and rotated towards parallelism with them. On a larger scale it seems very probably that even though the major foliation (S_2) of the schists is steeply dipping and there appear to be very great thicknesses of metamorphosed sediments, the formations or groups as a whole are subhorizontal and tightly folded. It does not seem likely that the inclination of the schist can be determined from the attitude of the foliation or bedding relicts within it; in which case there seems no way to determine its attitude. In other parts of Tasmania it has been found that S_0, S_1 and S_2 are commonly almost parallel because of repeated isoclinal folding.

Remains of up to 3 or 4 foliations are present in some of the schists but generally only 1 or 2 are recognizable macroscopically. Bedding and a single, slightly oblique foliation can be recognized in Fisher Group quartzites and slates. A strong and a weak foliation can be seen in most Dove Schists. Generally only one major foliation is recognizable in Howell schists and quartzites. This is subparallel to bedding relics and parallel to the axial surface of small folds.

The foliations strike a little north of west and dip steeply to the north or to the south (fig. 3).

Spry (1958) described mesoscopic and macroscopic folds of various dimensions. In the petrographic section it was shown that S_0 and S_1 and probably S_2 were folded on a microscopic scale during the metamorphism. No detailed study has been made of the fold styles but many are similar folds of S_0 and S_1 associated with considerable flow along the axial surfaces (S_2). Some thin quartzite layers within schist show extreme thinning of limbs and thickening of cores and the formation of fold mullions. Some of the folds in the Fisher quartzites appear to be simple parallel folds.

Discussion later suggests that the major mapped folds are Devonian in age and that no large-scale Precambrian structure is visible. For similar reasons to those given for the Frenchman's Cap area it is suggested that there may be a very large recumbent fold with an east-west axis. It is possible to draw a profile of a complex structure to fit the stratigraphy suggested by Spry (1958), Jennings (1958), and Spry (1962a) showing a large Precambrian recumbent fold distorted by Devonian antiforms and synforms (fig. 4). This is named the Borradaile Fold.

Evidence given later suggests a hinge several miles north of the Fisher River on the Mersey Forestry Road. The contact between Dove Schist and Fisher Group is interpreted as the zone in which the foliation becomes vertical then overturned at the hinge of the recumbent fold.

The rocks in this area are not strongly lineated and measurements of lineation directions are too few to give an understandable pattern. A plot of poles to lineation of all kinds is given in fig. 3. The lineation lies in the foliation and the diagram shows that the lineation plunges at moderate angles to east or west.

The varieties of lineation include fold axes, fold mullions, ribs on quartzites, crenulations in schist, large grooves in quartzite and rarely, intersection of foliations of various kinds.

Three reasons are possible for the spread in direction in fig. 3 :

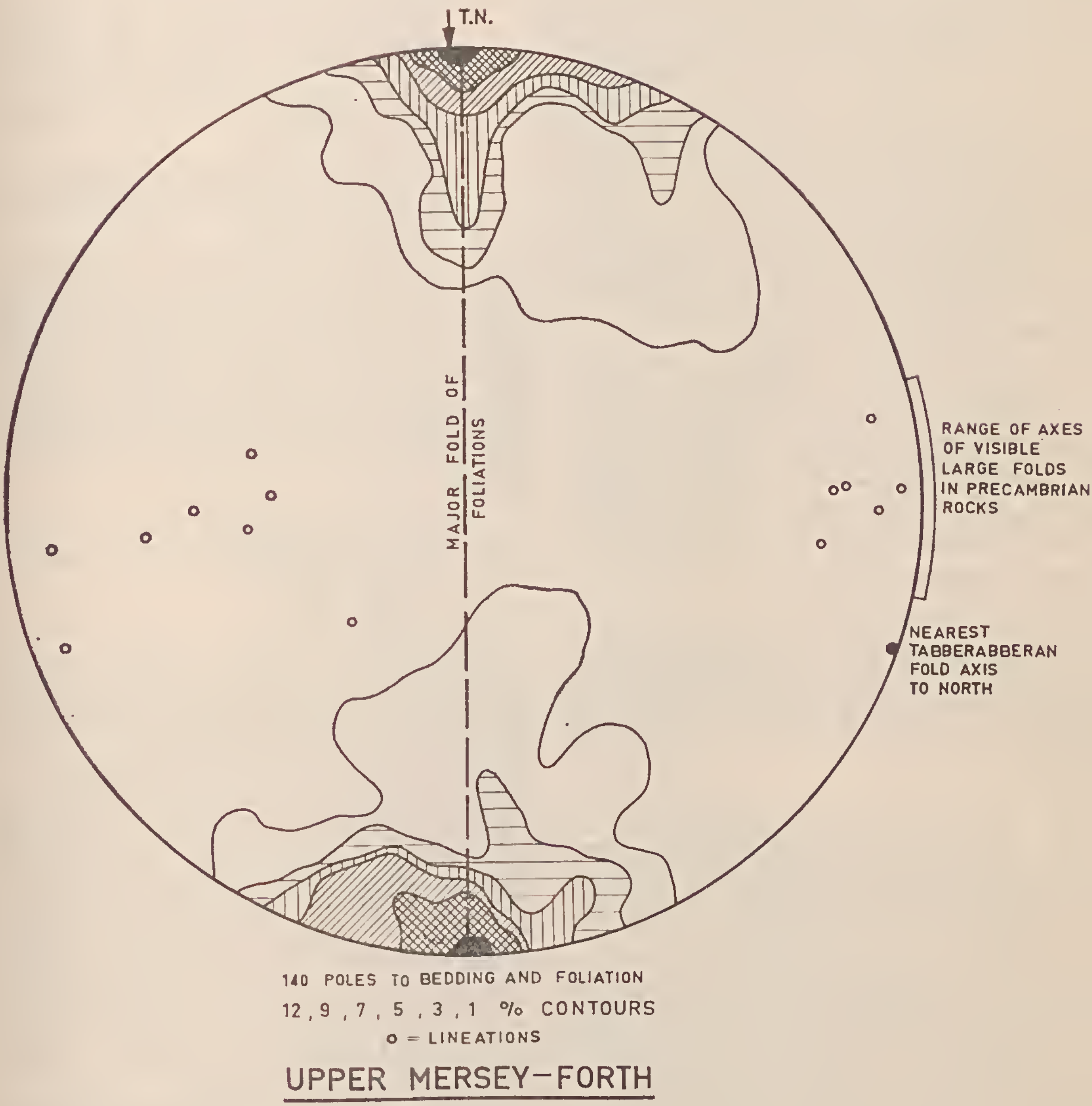

Fig. 3.—Stereographic projection of structural data for the Mersey-Forth area showing Devonian folding of Precambrian foliations.

(1) Lineations of different kinds and ages (e.g. L_1 and L_2) may have been grouped together. In several places it has been possible to see two lineations in the one specimen; one due to metamorphic minerals plunging west and a later coarse lineation due to crenulations of the foliation plunging east. In general the strongest lineation is parallel to the axes of adjacent small folds but the relations are not always so simple. A large amount of the crest of the overturned anticline beneath the Walter's Marsh bridge is exposed in the river. Two lineations run down the fold; one (L_2?) is parallel to the axis but the other (L_1?) is 10° away.

(2) The few available measurements suggest that the east-plunging lineations are confined to the southern part of the area, i.e. to the Howell Group around Walter's Marsh. It will be shown later that much of the large-scale folding took place in the Devonian so that the spread in the lineation direction may be due to cross folding on north-south axes. The fold axes in the Palaeozoic rocks to the north plunge generally to the E.S.E. so that it is possible that lineations which originally plunged westerly have been rotated around to plunge easterly in part of the area.

(3) Measurements of lineations in very small areas show that the rocks were originally not completely homoaxial. An exposure of Howell Group quartzite in a road cutting on the Forestry Road 2 miles north of the Arm River exposes a number of isoclinal folds. The folds are all of the same style and their axial planes are parallel, but fold axes only a few feet apart plunge west at angles ranging from 5° to 45°. A similar relationship has been found by Burns (pers. comm) in similar metamorphic rocks on the lower Forth River.

TABBERABBERAN STRUCTURES

Faults

It is very difficult to recognise faults through the Precambrian rocks in this area but a number of minor post-metamorphism faults parallel to the major folds occur to the north and south of the Mersey - Arm junction. A number of other possible faults and fault directions were tentatively discussed by Spry (1958). Their age is not known but they are suspected to be Devonian.

Folds

Spry (1958, p. 136) indicated that the rocks were folded on all scales ranging from microscopic dimensions up to structures many miles across. Many of the tiny crenulations and shear folds up to a hundred feet or so appear to be related to the metamorphism and were described earlier as Precambrian.

The larger folds (first and second order folds of Spry, 1958) are probably Tabberabberan synforms and antiforms. The stereographic plot (fig. 3) of the foliation in the Precambrian rocks shows that the poles lie on a partial great circle which represents a number of folds with horizontal axes trending east-west. Large folds in the Precambrian rocks have been mapped in this direction (fig. 1 and Spry, 1958; Jennings, 1958) and the axis of the nearest fold in the Palaeozoic sediments to the north plots close to this direction. The major unconformity between the Precambrian schists and the overlying Cambrian or Ordovician sediments is not a strongly angular one. The dip and strike of the schists and sediments is similiar and the Precambrian foliation must have been fairly flat prior to the Cambrian sedimentation.

The close structural relations between the Precambrian and Palaeozoic rocks might suggest that perhaps the metamorphism as well as much of the folding occurred in the Tabberabberan Orogeny but the following evidence shows that this is not so:

1. The contact between the Dove Schist and the overlying Palaeozoic sediments is sharp. Regionally metamorphosed schist underlies unmetamorphosed sandstone except where Devonian granite intrudes along the contact.
2. The Cambrian and Ordovician conglomerates contain pebbles identical with the underlying metamorphic rocks.
3. Cleavage in the Palaeozoic sediments is parallel to the axial surfaces of the large folds but the foliations in the Precambrian rocks have been folded by these folds.

Two of the largest structures were named the Mersey Syncline and the Fisher Anticline. It is proposed to change the name of the former to the Mersey Synform as its structure is even more complicated than originally thought. The synclinal form proposed by Spry (1958) has been confirmed by Jennings (1958) and Paterson (per. comm.). Dips are steep (commonly around 60°, rarely lower than 55° and many 85° to 90°) but bedding is clear in most exposures and dips are northerly in the southern part and southerly in the northern part. At least three smaller folds occur within the synform.

STRATIGRAPHY

Three separate lithological units have been recognized:

Dove Schist

Fisher Group

Howell Group

The Howell Group appears to dip beneath the Fisher Group 1½ miles north of Walter's Marsh, and also 1½ miles west of the Mersey-Arm junction. However, the Fisher Group appears to dip beneath the Howell Group 2 miles north of the Mersey-Arm junction.

The relations of the Dove Schist and Fisher Group on the Mersey Forestry Road, north of the Mersey-Fisher junction, are difficult to understand. In general both rock types dip away from the contact. It is possible that although the foliation of the Dove Schist dips north, the bedding (not now visible) dips south beneath the Fisher quartzites. Detailed inspection of the contact zone along the Mersey Forestry Road, shows that as the contact is approached from the north, the foliation in the Dove Schist becomes steeper until it is vertical; there is a transition zone where thin quartzites are interbedded with schist and then as the dip becomes flatter (now to the south) massive Fisher quartzites appear. This is interpreted as part of an overturned contact near the hinge of the hypothetical Borradaile Fold as shown in the section in fig. 4.

Ripple marks are possibly sufficiently abundant in the Fisher quartzites to allow attitudes to be determined and detailed mapping may clarify the position although outcrop is sparse.

At present it is not possible to determine the true stratigraphic sequence but structurally the Dove Schist appears to rest on the Fisher Group which in turn rests on the Howell Group.

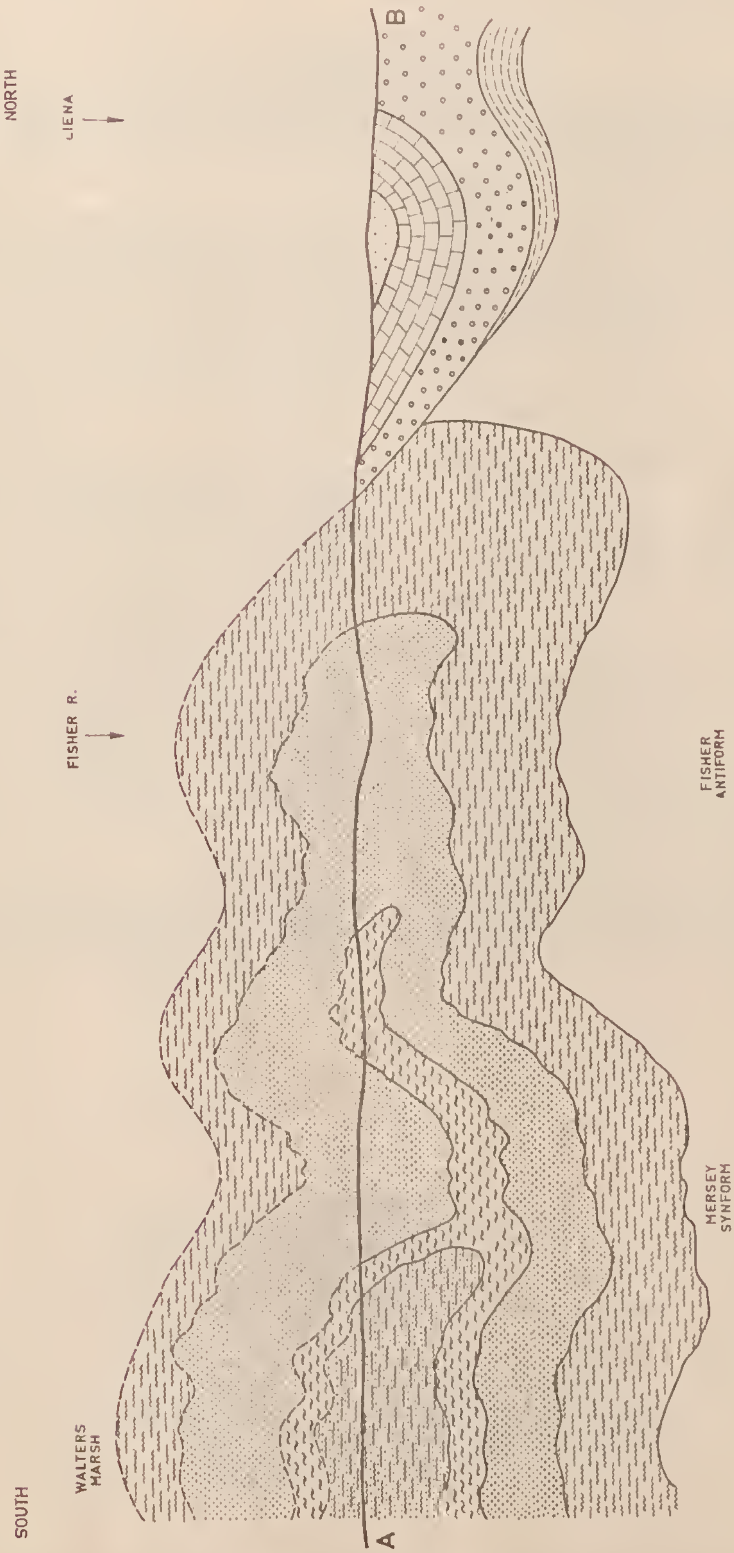

Fig. 4.—Cross section along the Mersey River showing Devonian antiforms and synforms superimposed on the hypothetical recumbent Borradaile Fold.

TABLE II

Chronology of Crystallization and Deformation of Schists from the Mersey and from Frenchman's Cap.

		F_1			F_2		F_3	
	Deformation Stage	pre	syn tectonic	post	syn tectonic	post	syn tectonic	post
DOVE SCHIST	quartz							
	muscovite							
	garnet							
	albite							
	biotite					?		
	chlorite							
	tourmaline			?		?		
	S produced		S_1		S_2		S_3	
	S folded		S_0		S_0, S_1		S_0, S_1, S_2	
HOWELL SCHIST	quartz							
	muscovite							
	garnet							
	albite							
	biotite							
	chlorite							
	S produced		S_1		S_2		S_3	
	S folded		S_0		S_0, S_1		S_0, S_1, S_2	
FRANKLIN SCHIST	quartz							
	muscovite							
	garnet							
	albite							
	biotite							
	chlorite							
	kyanite							
	S produced		S_1		S_2		S_3	
	S folded		S_0		S_0, S_1		S_0, S_1, S_2	

CONCLUSIONS

The Howell Group and Dove Schist are dominantly metapelites belonging to the quartz - albite - epidote almandine subfacies of the Greenschist Facies whereas the Fisher Group is mainly quartzitic with minerals and textures more characteristic of the quartz - albite - epidote - muscovite - chlorite subfacies. Rocks containing the two different mineral assemblages are closely associated in the field.

The Howell Group and Dove Schist are thus similar in lithology and structure to rocks described previously from Frenchman's Cap (Spry, 1962b) and as the petrological and structural problems are the same they need not be discussed at length here. The chemical analyses in Table 1 show that rocks of similar compositions (e.g. slate No. 7390 from the Fisher Group and the garnet schists Nos. 7387 and 7388 from the Howell Group) are chemically similar but their mineralogy indicates that they have been metamorphosed to considerably different grades.

The structural simplicity and low metamorphic grade of the Fisher Group suggests that it might be younger than the Dove Schist and Howell Group. It has features in common with the younger Precambrian rocks (Spry, 1962a) as well as the older Precambrian Mary Group.

The fabric evolution of the albite schists in the Dove, Howell and Franklin Groups are compared in Table II.

As shown earlier the largest visible structures are a series of synforms and antiforms shown on the maps of Spry (1958) and Jennings (1958) but it does not seem possible to derive a *simple* structural explanation compatible with all the field observations. An earlier explanation (Spry, 1958) attempted to reconcile various conflicting points by postulating large strike faults. Later mapping by Jennings (1958), S. J. Paterson and the author has failed to confirm the existence of these faults.

An hypothesis involving a large recumbent fold is presented in an attempt to overcome these difficulties even though at present there seems to be no way to check its validity. It is compatible with all field observations of the attitudes of foliations, bedding and contacts and is the kind of structure which has been found elsewhere in the world in rocks which are similarly metamorphosed and which have similar small-scale structures.

The large Precambrian recumbent fold has a core of Howell Group surrounded by Fisher Group then Dove Schist. The direction of the axis of this fold is related to the lineation and probably plunges rather flatly to the west but may be warped. The Fisher-Dove contact is interpreted as the hinge of the fold which is thus shown as closing to the north.

This is similar to the structure postulated at Frenchman's Cap and has a similar axial trend. A comparison of the chronology of crystallization and deformation of Franklin and Howell Group schists shows many similarities. The differences are :

1. The F_3 phase produced much more intense folding of S_2 at the Mersey than at Frenchman's Cap.
2. Biotite was formed during F_3 at the Mersey but there was no significant mineral growth at Frenchman's Cap.
3. Albite is restricted to the intertectonic period between F_1 and F_2 at Frenchman's Cap but may possibly have crystallized after F_2 in some Dove Schist.

F_1, F_2 and F_3 do not necessarily mean the same thing in the two areas.

F_3 at Frenchman's Cap appears to consist mainly of Palaeozoic movements whereas that at the Mersey may be mostly Precambrian.

The correlation in Table II however, is preferred. It is based on detailed similarities between the nature of S_1 relics, and the fact that S_2 is dominant in the schists and is the axial surface of the minor folds.

It is considered that metamorphic mineral assemblages characteristic of chlorite to garnet grade were produced in large flat sheets of rock during F_1 and that these were folded into large recumbent folds during F_2 at chlorite grade.

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